Piloted Simulation Investigation of Helicopter Flight Envelope Tactile Cueing

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Two ground-based piloted simulation trials of helicopter flight envelope tactile cueing have been conducted. The objective of the trials was to develop methods of helping the pilot to observe flight envelope limits while conducting precise and demanding evaluation tasks. In one trial, large-displacement conventional inceptors were used; in the other, short displacement sidesticks. The inceptors in both trials were programmable and active.

Figure 1 shows the algorithm that was used to estimate the inceptor position corresponding to a vehicle limit. A polynomial neural network (PNN) provided lead estimate of the limit variable, which was then adjusted using a simple adaptation algorithm before being compared with the preset limit to determine the corresponding inceptor position. A tactile force breakout which the pilot could override (softstop) was then driven to the inceptor location corresponding to the limit. The simulated limits were time-varying in nature.

Figure 2 shows four time-histories of torque, collective position, and collective force for the four active sidestick test configurations. The movement of the transient/do-not-exceed boundary can be seen as the torque value transitioned above and below the continuous limit of 80 percent. The pilots were required to respect the limit using the instrument cues and the tactile cues. For the configurations with tactile cueing, the softstop movement associated with the transient/do-not-exceed boundary can be seen. The pilot's input tracked the softstop as it moved downward in accordance with the cueing algorithm. The collective force contributed by the softstop is indicated. Typically, 2–3 times the friction force was held when riding against the softstop. Maintaining this force in order to achieve maximum performance was associated with improved pilot acceptance and task performance.

The following major points were noted. The programmable nature of the active sidesticks enabled implementation of all conventional inceptor functionality including trim follow-up, beep trim, and trim release, and yielded favorable pilot commentary regarding posture, feel characteristics, and controllability. With tactile cueing, conventional inceptors and the sidesticks yielded nearly equivalent performance. For both types of inceptors, tactile cueing significantly reduced the time required to reach the envelope limit, increased the dwell time at the limit, reduced exceedances, and improved pilot opinion. Tactile cueing enabled the pilots to easily track and respect notional dynamic limits designed to account for accumulated fatigue damage. Tactile cueing enabled the pilots to easily track both torque and rotor stall limits simultaneously while performing an aggressive turning task with their attention focused entirely outside the cockpit.

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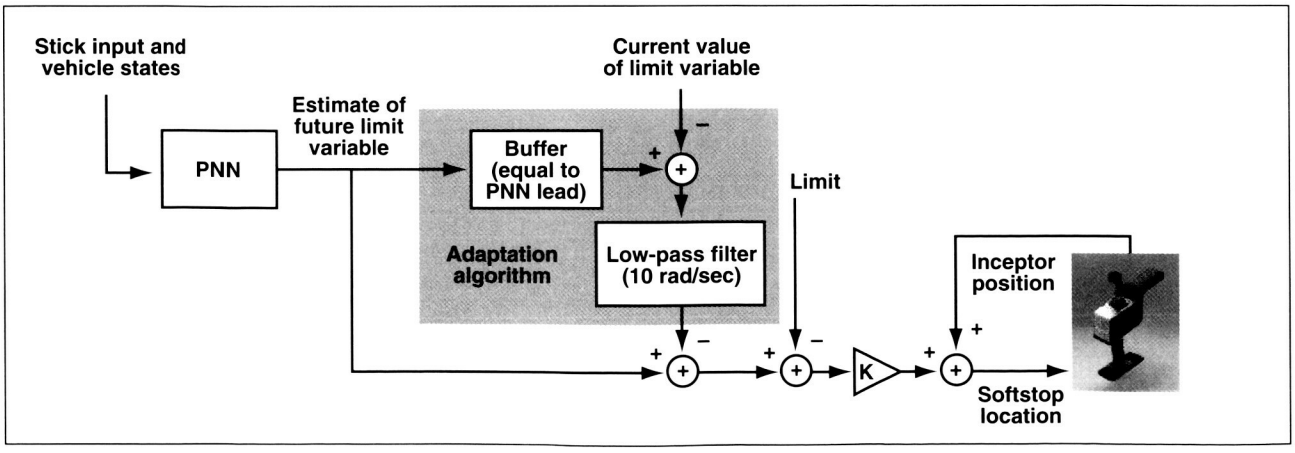

Fig. 1. Softstop location calculation using PNN.